

layer 4b. For example, as in Fig. 33, the MR-improving layer 4 may be an alloy layer 4c that comprises elements not forming solid solution with the essential components constituting the magnetic layer 1. To the alloy layer 4c in this case, the same as above for the laminate film could apply. Concretely, for example, where the magnetic layer 1 is of Co or a Co alloy, the alloy layer 4c comprises, as the essential constituent element, at least one selected from three elements of Cu, Ag and Au. Where the magnetic layer 1 is of an Ni alloy, the alloy layer 4c comprises, as the essential constituent element, at least one selected from four elements of Ru, Ag, Au and Cu.

The alloy layer 4c may comprise at least one additional element in addition to the essential constituent elements noted above. As the additional elements, used are elements capable of forming solid solution with the essential constituent elements of the alloy layer 4c so as to prevent phase separation in the layer 4c. For example, when the essential constituent element of the alloy layer 4c is Cu, the alloy for the layer 4c shall contain a noble metal, including, for example, Cu-Au, Cu-Pt, Cu-Rh, Cu-Pd, Cu-Ir, etc. When the essential constituent element of the alloy layer 4c is Ag, the alloy for the layer 4c may be a noble metal alloy, including, for example, Ag-Pt, Ag-Pd, Ag-Au, etc. When the essential constituent element of the alloy 4c is Au, the alloy for the layer 4c may also be a noble metal alloy, including, for example, Au-Pt,

Au-Pd, Au-Ag, Au-Al, etc.

Of the alloys noted above, it is desirable that the two elements constituting the alloy layer 4c for the MR-improving layer 4 could form solid solution to a level of at least 10 %. For example, preferred are alloys of Au-Cu, Ag-Pt, Au-Pd, Au-Ag, etc. As mentioned above, various types of morphology could apply to the MR-improving layer 4. For example, the MR-improving layer 4 may also be a laminate film composed of the metal film 4a and the alloy layer 4c, as in Fig. 34.

Where the free layer 1 is of a Co-based magnetic material, it is desirable that the MR-improving layer 4 which acts as the underlayer for the free layer 1 is of a metallic material having the same fcc-crystal structure as the Co-based magnetic material has, or of an hcp-structured metallic material capable of readily orienting the overlying film in fcc-orientation. In view of those points, Cu, Au, Ag, Pt, Rh, Pd, Al, Ti, Zr, Hf, Ir and their alloys such as those mentioned above are preferable materials for constituting the MR-improving layer 4. Further, when the MR-improving layer 4 is of a laminate film or an alloy layer of those metals, it is effective for reducing the magnetostriction in the free layer 1 of a Co-based magnetic material such as Co-Fe alloys, etc., as will be described in detail hereunder.

It is desirable that the thickness of the MR-improving layer 4 is at least 2 nanometers, in order that the layer 4

could have the function as a underlayer. However, if too thick, the layer 4 will increase the shunt current flow to thereby reduce the MR ratio in the film 8. Therefore, it is desirable that the thickness of the MR-improving layer 4 is at most 10 nanometers, more preferably at most 5 nanometers.

The MR-improving layer 4 has the function of improving the thermal stability of the spin valve film 8, the function as a specular reflection film (interfacial reflection film) in the spin valve film 8, the function of still keeping high MR ratio even if the free layer is thin, the function of reducing the magnetostriction in the free layer 1 of a Co-based magnetic material, and the function of controlling the microcrystalline structure of the spin valve film 8. Based on those function, the MR-improving layer 4 improves the MR characteristics of the spin valve film 8. The functions of the MR-improving layer 4 are described in detail hereunder.

First referred to is the process of thermal degradation of spin valve films. One reason for the thermal degradation of the MR characteristics of spin valve films during annealing is that the specular reflection on the sides of the magnetic layers 1 and 2 not contacted with the nonmagnetic spacer layer 3 will vary during annealing. Fig. 35A to Fig. 35C show the reduction in the MR ratio in spin valve films after thermal treatment. In those,  $IF_s$  indicates the interface with spin-dependent scattering thereon, and  $IF_M$  indicates with no